

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
22 February 2001 (22.02.2001)

PCT

(10) International Publication Number
WO 01/12332 A2

- (51) International Patent Classification⁷: **B02C 19/00** (US). HAMPTON, Arthur; 24 Dark Lane, Wargrave, Reading, Berks RG10 8JU (GB).
- (21) International Application Number: PCT/GB00/03071
- (22) International Filing Date: 9 August 2000 (09.08.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
09/372,096 11 August 1999 (11.08.1999) US
- (81) Designated States (*national*): AU, BR, CA, CN, DE, ES, GB, IL, IN, JP, KP, KR, MX, NO, NZ, PL, PT, RO, RU, TR, UA, YU, ZA.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- (71) Applicant: **HELIX COMMUNITIONS LIMITED** [GB/GB]; Apple Tree House - Main Street, East Haddon, Northants NN6 8BU (GB).
- Published:
— Without international search report and to be republished upon receipt of that report.
- (71) Applicant and
- (72) Inventor: **YOUNDS, Mark** [GB/GB]; 158 Monkleigh Road, Morden, Surrey SM4 4ES (GB).
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
- (72) Inventors: **JARRETT, Colin**; Apple Tree House-Main Street, East Haddon, Northants NN6 8BU (GB). **BURNHAM, Jeffrey**; 2741 Ardisia Lane, Naples, FL 34109

WO 01/12332 A2

(54) Title: METHODS AND APPARATUS FOR SEWAGE PROCESSING AND TREATMENT

(57) Abstract: An apparatus for processing and treating biosolids such as sewage, whereby drying and elimination of pathogens takes place, comprises a feed assembly with conical section and inlet tube having a discharge area and inlet area for the passage of air and sewage and a rotor for creating reverse vortices in a cyclonic air-stream within the conical section and inlet tube. A formula is utilized which is configured to also create a fundamental standing wave, to assist treatment and processing of sewage, and a centripetal boundary envelope inside the conical section.

METHODS AND APPARATUS FOR SEWAGE PROCESSING AND TREATMENT**Background****1. Field of the Invention**

The present invention relates to apparatus and methods for processing sewage, and to an impeller suction fan for processing such materials. In particular, but not exclusively, this invention relates to a formula designed apparatus for treating and processing sewage and biosolids and to methods for treating sewage and biosolids.

2. Description of the Background

Apparatus for granulating materials whereby no grinding element is involved are well known. The principle of such apparatus is to granulate the material due to collision and self-abrasion between the individual lumps or aggregates of the material within at least one vortex formed in a cyclonic air stream.

U.S. Patent No. 5,402,947 describes such an apparatus in which an air stream at high pressure, together with the material to be granulated, is fed into a cyclone chamber. A single vortex formed within the chamber entraps the material and subjects it to violent turbulence thereby causing it to break up through collision and self-abrasion. However, the movement of the material within the vortex causes severe abrasion and wear of the walls of the cyclone chamber.

It has been found that the pressure of the air stream within the conduit is an important factor in the processing process, sub atmospheric pressure being obligatory and the actual working pressure critical to efficient operation. Therefore, the air must be drawn through the conduit by a suction fan or blower through which the air stream and entrained particulate material must eventually pass. The fan would, therefore, be subject to severe wear from the passage therethrough of the

particles entrained within the air stream which are traveling at very high velocities. Such pneumatic or vacuum comminution is described by U.S. Patent No. 3,147,911. This particular comminution was utilized for crop grinding. It comprised a vertically rotating fan in a housing having a horizontal inlet along the fan axis. However, the fan was subject to severe wear with unacceptable metal losses from the blades of the fan. Furthermore, the apparatus was not suitable for processing harder material such as stone, coal, cement etc.

Other devices and methods for or relating to treatment of materials such as sewage are known. These include those methods and devices disclosed in U.S. Patent Nos. 3,147,911; 3,255,793; 4,390,131; 4,391,411 and 4,892,261, and PCT/GB98/00422, all of which are specifically incorporated herein by reference in their entirety.

New legislation in many countries is making it increasingly difficult to dispose of sewage into the sea or spread it on land, due to its high content of pathogens. Currently, techniques of drying the sewage, mixed with, for example, lime to combat pathogens, are very expensive. There is therefore a need for methods and apparatus for the efficient and effective processing and treatment of sewage.

Summary of the Invention

The present invention seeks to overcome the above-mentioned disadvantages by providing apparatus capable of processing materials, such as biosolids, efficiently whilst minimizing wear of the fan. By a special processing technique of the present invention one can remove some of the pathogens and dry the sewage at the same time. Market research has shown that the current cost of treatment can be dramatically reduced when using the apparatus of the present invention. It will enable sewage companies to substantially reduce transport costs. The end product

can also be used in many applications such as fertilizer or to generate electricity.

It has been found that a cyclone created in a stream of air passing through a conduit, preferably of circular cross-section, the centripetal forces created by the motion of the air stream pull any particulate material entrained in the air stream away from the walls of the conduit and towards its central region. If a wide range of sonic frequencies are created within the conduit, a pattern of powerful vortices are created in the air stream. Energies are released by conversion of the potential energy to kinetic energy due to the stresses created within the cyclone which causes a minute explosion. The vortices of the cyclone take the form of implosions which are capable of breaking the material up further into smaller particles.

It has also been found that the vortices created in the cyclonic air stream carry further harmonic frequencies generated by the specially designed apparatus; this sets up a pulse from the standing wave configuration within the system, and this causes pockets of air within the standing wave to achieve a velocity beyond the sonic range. This can be tuned for a particular type of material which enhances the ability of the vortices created to break up very hard and soft materials such as stone and to dry materials.

This phenomenon can be achieved by apparatus for processing a material, according to a first aspect of the present invention comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the cyclonic air stream includes non conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the apparatus and

induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

Preferably, the cross-sectional area of the cyclone chamber is within the range of 24 to 29% of the cross-sectional area of the inlet of the fan; more preferably, it is approximately 26% of the cross-sectional area of the inlet of the fan.

Preferably, the area of the inlet of the fan is within the range of 28 to 35% of the fan's circumferential outlet area; more preferably, it is approximately 32% of the fan's circumferential outlet area.

Preferably, the discharge area of the outlet of the fan is within the range of 19 to 27% of the fan's circumferential outlet area, more preferably, it is approximately 24% of the fan's circumferential outlet area.

Preferably, the length of the cyclone chamber is variable. This may be achieved by the cyclone chamber comprising a conduit and a sleeve concentric with and in slidable engagement with the conduit such that movement thereof varies the length of the cyclone chamber.

Preferably, the apparatus further comprises a fan casing for supporting the impeller suction fan, the fan having a plurality of radially extending vanes. The clearance between the outermost edge of the vanes and the fan casing may vary around the circumference of the fan such that, in operation, at least two-thirds of the vanes are fully pressurized. Further, the forward edge of each vane of the fan may be 1/24th of the diameter of the fan greater than the radius of the cyclone chamber. The fan casing may be lined with a layer of high abrasion resistant material and the layer of high abrasion resistant material may further comprise a groove extending circumferentially around

the fan casing. Each vane may be coated with a high abrasion resistant plastics material.

Preferably, the apparatus further comprises a separator for separating the granulated material from the cyclonic air stream.

Preferably, the feed assembly comprises a hopper extending partly into the cyclone chamber so that the material is fed into the path of the cyclonic air stream, or alternatively, it comprises a hopper and an auger-driven conveyor, the conveyor extending partly into the cyclone chamber or hopper so that the material is fed into the path of the cyclonic air stream. The distance between the feed assembly and the fan inlet may be adjustable.

Preferably, an externally generated frequency is induced into the cyclonic air stream.

Preferably, the material is processed within the cyclonic air stream before the air stream is disturbed by the fan.

The apparatus may include any one of or any combination of the following processes: processing, drying, and dewatering.

This phenomenon can be achieved by an impeller suction fan for a processor, according to a second aspect of the present invention comprising a central hub and plurality of vanes extending radially from the hub for creating a cyclonic air stream, wherein the cyclonic air stream includes non conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the processor and induced: supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

Preferably, the vanes extend forwardly from the hub of the fan at an angle within the

range of 30° to 50° to the axis of rotation of the fan; more preferably, the vanes of the fan extend forwardly at an angle of 45° to the axis of rotation of the fan.

Preferably, each of the vanes has a slot extending substantially parallel to the axis of rotation of the fan and having a width within the range 0.5 to 4% of the overall length of the vane. The slot may be located at a distance from the hub of the fan at the edge of the impeller inlet.

Preferably, the fan further comprises an interrupter located on the hub for disturbing the air within a zone immediately in front of the hub. The diameter of the interrupter may be approximately equal to the diameter of the hub.

Preferably, each vane extends radially at an angle within the range of 3° to 17° to the radius of the fan.

Preferably, each vane is concave in profile such that the concavity faces in the direction of rotation of the fan.

Preferably, each vane is coated with a high abrasion resistant plastics material.

Preferably, curvature of the vanes is adjusted for a particular material by computer-aided design to take account of fluid dynamics and wear rates.

The apparatus for processing a material according to the first aspect of the present invention may incorporate an impeller suction fan according to the second aspect of the present invention.

This phenomenon can also be achieved by apparatus for processing a material, according to a third aspect of the present invention comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into

the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the cross-sectional area of the cyclone chamber is within the range of 24 to 29% of the cross-sectional area of the inlet of the fan. Preferably, the cross-sectional area of the cyclone chamber is approximately 26% of the cross-sectional area of the inlet of the fan.

This can also be achieved by apparatus for processing a material, according to a fourth aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the area of the inlet of the fan is within the range of 28 to 35% of the fan's circumferential outlet area. Preferably, the area of the inlet of the fan is approximately 32% of the fan's circumferential outlet area.

This can also be achieved by apparatus for processing a material, according to a fifth aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the discharge area of the outlet of the fan is within the range of 19 to 27% of the fan's circumferential outlet area. Preferably, the discharge area of the outlet of the fan is approximately 24% of the fan's circumferential outlet area.

This can also be achieved by apparatus for processing a material, according to a sixth aspect of the present invention, comprising a cyclone chamber; a fan casing for supporting an impeller suction fan, the fan casing having an inlet and an outlet; an impeller suction fan having a

plurality of radially extending vanes for creating a cyclonic air stream within the cyclone chamber via the inlet of the fan casing; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the clearance between the outermost edge of the vanes and the fan casing varies around the circumference of the fan such that, in operation, at least two-thirds of the vanes are fully pressurized.

This can also be achieved by apparatus for processing material, according to a seventh aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the length of the cyclone chamber is variable. In this way the length of the cyclone chamber can be adjusted to tune the apparatus to achieve the standing wave at the particular harmonic frequencies generated by a specially designed fan.

This can also be achieved by apparatus for processing a material, according to a eighth aspect of the present invention, comprising a cyclone chamber; a fan casing for supporting an impeller suction fan, the casing having an inlet and an outlet; an impeller suction fan having a plurality of radially extending vanes for creating a cyclonic air stream within the cyclone chamber via the inlet of the fan casing; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the forward edge of each vane of the fan is $1/24$ th of the diameter of the fan greater than the radius of the cyclone chamber.

This can also be achieved by providing an impeller suction fan, according to a ninth aspect of the present invention, comprising a central hub and plurality of vanes extending radially from the hub for creating a cyclonic air stream, the vanes extending forwardly from the hub of the

fan at an angle within the range of 30 to 50° to the axis of rotation of the fan. Preferably, the vanes extend at an angle of 45° to the axis of rotation.

This can also be achieved by providing an impeller suction fan, according to a tenth aspect of the present invention, comprising a central hub and a plurality of vanes extending radially from the hub for creating a cyclone air stream, each of the vanes having a slot extending substantially parallel to the axis of rotation of the fan and having a width within the range 0.5 to 4% of the overall length of the vane.

This can also be achieved by providing an impeller suction fan, according to an eleventh aspect of the present invention, comprising a central hub; a plurality of vanes extending radially from the hub for creating a cyclonic air stream, and an interrupter located on the hub for disturbing the air within a zone immediately in front of the hub.

In providing apparatus with an impeller suction fan in accordance with any one of the criteria mentioned above or any combination of these, the vortices created inside the chamber are such that the power is optimized. This is due to the harmonic frequencies which create high energy pockets which can cause the breakup of very hard material. Consequently rocks are powdered and material dried at a distance from the impeller within the cyclone chamber. Therefore, the turbulence created in the zone immediately in front of the impeller only play a very minor part in breaking up and drying the material. The design of the impeller, in relation to the fan inlet area, the diameter of the inlet tube and the length of the feed-in tube, combined with the right number of blades on the impeller, rotating at a specific speed, etc., can dramatically improve results and reduce abrasion.

The apparatus and fan produce an harmonic/frequency which sets up pulses from the standing configuration within the system, and this is critical because, on occasion, pockets of air

through the standing wave achieve a velocity beyond the sonic range. These conditions when optimized by the various aspects of the present invention, i.e., high local vorticity and high energy dissipation, will in some cases produce Abrikosov vortices. When hard rock is processed by the machine, which has only one moving part, the ions orbiting the Abrikosov vortices will collide and may produce fusion.

Material is comminuted and/or dried before reaching the impeller by a combination of thermal shock, cavitation, sudden extremes of pressure and frequency/harmonic interference which is sometimes beyond the sonic range.

The apparatus of the present invention is capable of grinding a material down by 1500:1, which is comparable with prior art devices which only achieve a reduction of 4:1.

The processing of the material may be further optimized by introducing an externally generated frequency into the cyclonic air stream.

A preferred embodiment of the invention for the processing and treating of sewage comprises: a conical section with an inlet tube; a rotor for creating reverse vortices upstream in a cyclonic air-stream, the rotor having an inlet for the movement of the air-stream and sewage, and an outlet corridor with exit tube; and a feed inlet tube for feeding the sewage into a centripetal boundary envelope in the conical section, within the reverse vortex for treating and processing the sewage in the conical section and rotor.

Other objects and advantages of the invention are set forth in part in the description which follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

Description of the Drawings

- Figure 1 Side elevation of part of the apparatus according to the present invention showing the fan in part section;
- Figure 2 Part sectional side elevation of an alternative feed assembly of the apparatus according to the present invention;
- Figure 3 Transverse cross-section of the apparatus of Figure 1 taken along the line 3-3.
- Figure 4 Plan view of a vane of the fan of the present invention;
- Figure 5 Cross-section of the vane of Figure 4 taken along the line 5-5;
- Figure 6 Cross-section of the vane of Figure 4 taken along the line 6-6;
- Figure 7 Cross-section of the vane of Figure 4 taken along the line 7-7;
- Figure 8 Detailed plan view of a vane of the fan according to the present invention;
- Figure 9 Profile of the vane of Figure 8;
- Figure 10A Side elevation of the interrupter according to the present invention;
- Figure 10B Plan view of the interrupter of Figure 10A
- Figure 11 Perspective view showing an embodiment of the apparatus according to the present invention.
- Figure 12 a Sewage treatment apparatus according to a preferred embodiment of the present invention.
- Figure 12 b Sewage treatment apparatus according to a preferred embodiment of the present invention.
- Figure 13 Sewage treatment apparatus according to a preferred embodiment of the present invention.

Figure 14 Rotor according to a preferred embodiment of the present invention.

Figures 15a-b Interrupter according to the present invention.

Description of the invention

In this description, unless otherwise indicated, general dimensions of the apparatus and its components are given together with the parameters which are by way of example only.

An embodiment of the apparatus according to the present invention is shown, in part, in Figure 1. The apparatus comprises a conical impeller suction fan 71 and a cyclone chamber 70. The cyclone chamber 70 is generally cylindrical and is arranged such that its longitudinal axis lies along the axis of rotation of the impeller suction fan 71.

The impeller suction fan 71 has an impeller 10 which typically has a diameter within the range 300 mm to 1220 mm. Smaller impellers can also be utilized in the apparatus of the present invention for certain laboratory, domestic, cosmetic or pharmaceutical applications. For an impeller of 610 mm diameter, the width of the impeller would be 196 mm. The impeller 10 is rotatably supported within a fan casing 19. To accommodate the impeller of diameter of 610 mm, the internal width of the fan casing would be approximately 203 mm. The casing 19 has an opening 63 in one of the side walls 61 thereof. The impeller 10 has an inlet 14 which is an annular ring and partly extends out of the casing 19 via the opening 63.

As can be seen from Figure 3, the casing 19 is generally spiral in shape having an outlet 72. The inner surface of the casing 19 may be lined with a wear plate (not shown) formed of a high abrasion resistant plastics material. The wear plate extends around approximately two-thirds of the circumferential area of the inner surface of the casing 19 from the point of minimum clearance

8-8. The wear plate helps to minimize wear of the casing wall. To further improve the performance of the wear plate, a groove may be formed in the wear plate which extends circumferentially around the casing to define a space which conforms to the air flows experienced within the casing 19. The clearance between the inner surface of the casing 19 and the outer edge 76 of the impeller 10 increases in the direction of rotation of the impeller 10. The point of minimum clearance 8-8 occurs at an angle 0 from the horizontal plane 9-9, which passes through the center of rotation. The differences between the clearances of the impeller of the present invention and the impeller described with reference to U.S. Patent No. 3,147,911 is depicted in Table 1 below:

Table 1

0	New Clearance	Old Clearance
	(mm)	(mm)
33	12.6	19.0
90	43.2	72.2
135	65.8	95.3
180	71.1	109.2
235	80.0	121.9
270	114.3	152.4

As can be clearly seen from the figures of Table 1, the clearances between the outer edge of the impeller of the present invention are reduced by approximately 30% so that at least two-thirds of radial vanes provided on the impeller 10 of the present invention are fully pressurized. Of the remaining vanes, at least 90° of travel, the first of the vanes has begun to depressurize and the remaining vanes are fully depressurized with the final vane just entering the zone of minimum clearance.

The discharge area is designed to be within the range of 19 to 27%, preferably 24%, of the fan's circumferential outlet area, and the area of the inlet of the fan is within the range 28 to 35%, preferably 32%, of the fan's circumferential outlet area. In the particular example specified, the discharge area is 457.2 mm multiplied by the width of the fan's discharge conduit 72.

The impeller 10 is keyed to one end of a shaft 16 which is supported by a bearing 17 mounted on the rear of the casing 19. A drive pulley 18 is fastened to the other end of the shaft 16. In operation, the pulley 18 is driven by a variable speed motor or internal combustion engine by means of at least one belt as shown in Figure 11. The impeller is driven at typical speeds of 4,500 to 7,000 rpm.

The cyclone chamber 70 comprises a cylindrical conduit 20 which, for the particular impeller mentioned above, has an inner diameter of 203.2 mm and a length of approximately 1.83m, such that the cross-sectional area of the conduit 20 is within the range of 24 to 29%, preferably 26%, of the cross-sectional area of the inlet 14 of the impeller 10.

One end of the conduit 20 is open to the atmosphere and is fitted with a cylindrical sleeve 24 in slidable engagement therewith. A slot 26 and locking clamp 25 enables the position of the sleeve 24 to be adjusted and locked into position, thereby varying the length of the conduit 20 to finely tune the harmonic frequencies of the air stream within the conduit during operation. The other end of the conduit 20 terminates in a frusto-conical section 21 which has an opening 62.

For an 380 mm diameter impeller having eight vanes operating at 5,760 rpm, the optimum length of the conduit 20 is between 786 mm (i.e., the circumference of the inlet area of the impeller) and 931 mm. For a 610 mm diameter impeller, at 5,760 rpm, the optimum length is 1,298 mm (i.e., again the circumference of inlet area) up to 1.851 mm.

Both optimum ranges given above are for when the machine runs at 5,760 rpm. However, in the case of 380 mm diameter impeller, the inlet tube length range would apply to an impeller speed range of between 5760 rpm to 6,827 rpm. The length of the conduit should not be less than 718 mm or more than 1,150 mm, and for the impeller of diameter 610 mm, not less than 1,126 or more than 1851 mm.

The cyclone chamber 70 is secured, for example, by welding, to one side of a common supporting bracket 22, the side wall 61 of the casing 19 being removably fitted to the other side so that the opening 63 of the casing 19 and the mouth 62 of the expander section 21 are coincident. Thus the inlet 14 of the impeller 10 extends partly into the expander section 21 of the cyclone chamber 70.

A hopper 23 for receiving the material to be granulated is mounted on the conduit 20 adjacent the open end thereof and partly extending into the conduit. The hopper may be slidably mounted (not shown) on the conduit 20 so that its distance from the impeller may be adjusted. Such an arrangement allows the material to be introduced into the conduit 20 at a position which ensures the most efficient granulation.

Figure 2 shows an alternative feed assembly 44 which comprises a hopper 40, an auger-driven conveyor formed by a conduit 43 in which a screw 41 is driven to rotate by a geared motor 42. The conduit 43 of the feed assembly 44 extends partly into the conduit 20 of the cyclone chamber 70 so that the material fed into the hopper 40 is conveyed by rotation of the screw 42 into the path of the cyclonic air stream during operation. Suitable supporting brackets (not shown) are provided for the feed assembly 44.

In circumstances where both gravity and auger-driven conveyor feed assemblies are

provided, it is preferred that the auger-driven conveyor is mounted on the lower end 23a of the gravity hopper 23. discharge there into and from thence into the conduit 20 of the cyclone chamber 70. An advantage of such an arrangement is that both feed assemblies may utilize the means for adjusting the distance of the feed assembly from the impeller. Furthermore, the feed assembly may comprise an enlarged air inlet to increase the air flow within the conduit.

Other types of feed assembly may also be utilized in the apparatus of the present apparatus, for example, a pneumatic conveyor.

Details of the impeller 10 of the present invention will now be described with reference to Figures 3 to 10.

The impeller 10 comprises a plurality of radially extending vanes 11. Preferably, the number of vanes 11 number between 4 to 12 depending on the type of material to be granulated. The vanes 11 may be formed of and further may be coated with a layer of high abrasion resistant material to protect the vanes 11 against metal contamination as well as to provide a cushion to protect brittle particles such as diamonds which are released from ore such as kimberlite to allow large diamonds which would otherwise be crushed to emerge intact.

Each of the vanes 11 are offset from the radius of the impeller by an angle within the range of 3 to 17°. The vanes 11 are equispaced about a hub 15. The innermost edge 28 of each vane 11 is fitted into a corresponding axially aligned slot 29 in the hub 15. The hub 15 is provided with a central bore 37 and keyway 30 for receiving and being secured to the shaft 16. The spine 27 of each vane 11 is flat along both its chord and span, defining an isosceles triangle depicted by lines 80 and 81 and the innermost edge 28. The apex of the triangle coincides with the center of the outermost edge of the vane 11.

As can be seen from Figures 5, 6, 7 and 9, the profile of the vane 11 on either side of the spine 27 is generally arcuate in cross-section. The vane further comprises vane extensions 31 which may be flat and are angled at approximately 20° relative to the surface of the spine 27, but is preferably curved with rounded leading edges as shown by the broken line 31a. This curve induces laminar air flows over the surfaces thereby reducing drag and improving the efficiency of the fan. Each vane 11 is generally concave, the concavity of each vane 11 facing the direction of rotation of the impeller 10. Preferably, the curvature at the outermost edge of the vane is 1 to 3 mm.

The vane extension 31 extends into the inlet 14 of the impeller 10 at which point a slot 100 is formed in the vane 11; see Figure 9. The slot extends in a direction substantially parallel to the axis of rotation of the impeller 10. The width of the slot is preferably 0.5 to 4% of the overall length 1 of the vane 11. Typically on a vane of length 154.5 mm, the width of the slot is 2 mm. The vane extension 31 extends forwardly from the hub 15 of the impeller 10 by an angle (α) to the axis of rotation of the impeller 10. The angle α is within the range of 38 to 50° ; for the particular vane of length 154.5 mm, the angle is 45° . The extension 31 extends in a forward direction at angle α to a point A to form a straight front edge 101. The point A is designed such that it extends at distance beyond the wall of the conduit 20 of the cyclone 70 by a distance of $1/24$ th of the overall diameter of the impeller 10.

The front edge 73 which extends beyond the extension 31 is secured to an annulus 13, the inner peripheral margin of which provides an annular ring 14 which forms the inlet of the impeller 10. The internal diameter of the inlet 14 is approximately 406 mm. The rear edge 74 of each vane is secured to a plate 75 which comprises an outer annular ring 34 and a frusto-conical central portion 35 which, at its inner end, is secured to the hub 15 to provide a rigid structure.

An interrupter 90 may be fitted into the central bore 37 at the front side of the hub 15 facing the inlet 14 of the impeller 10. The interrupter is shown in Figures 10a and 10b. It comprises a disc 91 mounted on a central spine 92. The spine 92 is screw threaded so that the interrupter 90 can be screw-fitted into the central bore 37 of the hub 15. The interrupter 90 further comprises a diametrical ridge 93 which is raised at one end. A hole 94 is bored through the raised portion of the ridge 93 at an angle of 45°.

The interrupter 90 disturbs the stationary air directly in front of the hub 15. The interrupter has a diameter approximately equal to the diameter of the hub 15.

The orientation and design of the impeller vanes can be further optimized by computer-aided design and can be further adjusted dynamically to compensate for any wear of the vanes. In particular, the degree of curvature of the vanes can be adjusted by computational fluid dynamics analyzing wear patterns created by a given product and redesigning the vane to give optimum freedom from abrasion.

The granulation and drying of a material may be further improved by introducing an externally generated frequency to the cyclonic air stream by means of a speaker or electrical feed, for example. Typical frequencies may be 25 to 28 Hz, 57.6 Hz, 576 Hz for a fan running at 5,760 rpm. Disassociation of water can be enhanced by introduction of a frequency of approximately 42.7 Hz.

A practical example of the apparatus according to the present invention is shown in Figure 11. It comprises a supportive framework 50 upon which is mounted the support bracket 22 to which the suction fan 71 and the cyclone chamber 70 are secured. A variable speed motor 57 with a drive pulley 58 is also mounted on the framework 50 and a belt 59 connects the drive pulley 58 to

the pulley 18 of the fan 71. The means for varying the speed of the motor 57 are not shown. A belt guard 60 provides protection from the moving parts.

A conduit 51 connects the discharge conduit of the fan casing 19 to a cyclone separator 52 and receiving hopper 55 which are also mounted on the supportive framework 50. The lower end 54 of the separator 52 discharges the granulated material into the receiving hopper 55 from which it can be taken as required via a chute 56 by opening a shutter 77. The separated, clean air is then discharged from an exhaust conduit 53 into the atmosphere either directly or via filters for removal of any fine dust.

In operation, the motor 57 is run up to speed and the length of the conduit 20 of the cyclone chamber 70 is adjusted by loosening the clamp 25 and moving the sleeve 24 axially until the optimum conditions are achieved for granulating a particular material by tuning the apparatus to the natural resonance frequency of the material. The sleeve 24 is then locked in situ by the clamp 25.

The types of materials which may granulated by the apparatus of the present invention ranges from coal, lignite, petroleum coke, mezotrace, oil shale, glass, drywall, ash, manure, sewage sludge, salt crystal, mineral and ore-bearing sand, black sand, grains such as soybeans, com, oats, barley, milo and rice.

The apparatus of the present invention can be utilized to dry wet clay, paper pulp, fish and bones into a fine powder. It is also useful for drying pigmentation cake which contains up to 50% water. The drying process is accomplished at a reduced length of time which using conventional methods has typically required at least 16 hours. It is assumed that the 4°C temperature and the free N₂ generated in the air flow suppresses combustion, which normally occurs when pigmentation feedstock is powdered. Sewage cake utilized for fuel in combustion type gassifiers can be dried and

deodorized by the apparatus of the present invention. Sewage slurry can be dewatered without pre-treatment, ideal for either fuel feedstock for plasma gasification and conversion into surplus town gas or chemical treatment processes for metal recovery and binding heavy metals against acid rain leachate as well as destroying all known pathogens in the process making it suitable for land reclamation. It can be utilized to process fish to fish meal on ship providing a 20% savings.

The apparatus can also be utilized to dry ceramics and mineral compounds. Comminution of these can be avoided by slowing down the speed of the fan and feeding the material close to or in the expansion section in front of the fan inlet. Mining slurries can be dried either in powder form or dewatered sufficiently for chemical treatment for extraction of metals.

The material to be granulated is fed into the hopper 23 and is introduced into the path of the cyclonic air stream created by the suction fan 71 within the conduit 20 of the cyclone chamber 70. The material is completely fragmented within the conduit 20 before entering the fan due to the tuned harmonics carried by the vortices within the cyclonic air stream and is drawn by the cyclonic air stream into the inlet 14 of the impeller 10. The size of the exhaust ducting can be varied to adjust the air flow through the system.

A safety cutoff mechanism may be installed. During normal operation, there is virtually no load, particularly if a DC constant torque motor is utilized to drive the fan. Therefore sensors can be provided to detect any increase in load, for example, due to a large particle hitting the fan, to activate a cutoff switch and brake.

The sensors may alternatively detect particularly large particles in transit such as diamonds and perform the same function. Sensors may also be utilized to detect large particles in the exhaust ducting and increase the speed of the fan to ensure that the material is finely granulated.

Alternatively, the feed rates or the cyclone separator can be adjusted upon detection of large particles.

The forces within the vortices of the cyclonic air stream may release hydrogen and oxygen gases from certain materials, for example, sewage sludge, to at least partly dry the material. In some circumstances it may be preferable to dry materials by heating the material, for example, by subjecting the material to microwaves, either as is fed into the conduit 20 of the cyclone chamber 70, within the conduit 20 itself or feed into the fan casing. Introduction of microwaves also promotes separation between metals and their ores. Further, disassociation of the water due to the result of shearing of the water at 4°C (its densest point) results in the formation of singlet oxygen such as O_3 and O_4 (ozone) which destroys odors in bacteria-contaminated products such as sewage cake. Further, H_2 , formed by the disassociation of water may recombine with some of the oxygen to form water which may be exhausted out via the fan or it may form around the inner surface of the conduit 20 and stream out of the open end of the conduit counter to the air stream within the conduit.

Typically, in the apparatus of the present invention, an impeller of 380 mm diameter having eight vanes running at a speed of 5760 rpm will dry 2.16 tons per hour of sewage (comprising 70% water, 30% solids), which has been diced into 4.5 cm^3 cubes. Further such an arrangement can granulate rock of 15 cm^3 at a rate of 5 tons per hour. Typically, a 610 mm diameter impeller having eight vanes will dry 3.6 tons of sewage per hour (comprising 70% water, 30% solids), diced into 7.5 cm^3 cubes or 3 granulate rock of 25 cm^3 at a rate of 8 tons per hour.

In the case of an impeller having eight vanes running at 5760 rpm, 3,145,728 pulses are generated by the blade and hub, according to the present invention, within the vortices, which greatly improves the drying and comminution process.

The present invention also relates to a novel sewage treatment apparatus and methods of using the apparatus to process and treat sewage. Specifically, this invention relates to a formula-designed apparatus and methods for the treatment and processing of biosolids.

The biosolids include materials selected from the group, sewage, sewage sludge, municipal sewage sludge, septage, manures, animal waste, slaughter house offal, pharmaceutical fermentation waste, industrial biosolids, waste products from the production of beer and wine, agricultural wastes, food biproducts and wastes, spent hens, paper mill waste, borgass, mushroom compost waste, and waste solids resulting from the growth of microorganisms. These materials are often disposed of in landfills or are burned. Both of these processes are not beneficial. It is the intent of this invention to modify said biosolids so that their value is enhanced and so that they may be used beneficially rather than be disposed.

Biosolids are produced during many industrial and municipal practices. For example sludge is produced from municipal wastewater and need to be dealt with by the producing community. New legislation in many countries is making it increasingly difficult to dispose of sewage or sludge into the sea or spread it on land, due to its high content of microorganisms and especially, pathogens. The microorganisms found in these biosolids are bacteria, fungi, viruses, parasites and algae. Currently, techniques of drying the sewage sludge, mixed with, for example, lime to combat pathogens, are very expensive. This invention creates sufficient kinetic energy to produce destructive forces within the apparatus employed to treat such biosolids that it is able to affect the microorganisms and pathogens in the biosolids by either bacteriostatic effects or bactericidal effects. The invention will dewater and remove both free and cell-bound water from the

biosolids at the same time as it is affecting the microorganism population. The invention will be able to pasteurize and/or sterilize all or some of the biosolids described above.

Market research has shown that the current cost of treatment can be dramatically reduced when using this apparatus. It will enable sewage companies to substantially reduce transport costs. The end product can also be used in many applications such as fertilizer or to generate electricity. As part of this method of creating beneficial materials the invention will reduce the particle size associated with each biosolid before treatment and granulate said biosolids to facilitate their being used in agriculture as fertilizers or animal food or by the public for gardening or horticultural practices. These materials will also be beneficated for utilization by municipalities in creating improved lawns, playing fields, berms or other public properties. It is further anticipated that these beneficated materials will be used by industries as new reagent products in the production of additional agricultural and food products.

The novel sewage processing treatment apparatus and methods have been used to process and treat centrifuged sewage containing 21.4% dry solids, at a rate of 4000 Kg per hour, with the expelled powdered product containing 70 to 77% dry solid, and removed at least 25 to 50% of the pathogens, due to a formula configuration of the apparatus which creates reverse vortices upstream in front of a rotor which also shears the sewage.

The resulting intense disruption, caused by the action within the reverse vortices in the cyclonic air-stream, together with the shearing action of the rotor's blades, will alter the chemical structure of the sewage, for example by turning some of the water in the sewage into gases such as hydrogen peroxide, hydrogen, oxygen and ozone and water vapor. So powerful is the reverse vortex that some of the water in the sewage is separated from the solid, in the form of pure water, and

returns back down the wall of the inlet tube while sewage is being fed in. High speed video photography has successfully recorded the existence of the reverse vortex. Powder and pure water has been seen coming back down the wall of the inlet tube. (Rocks introduced into the conical section traveled in the opposite direction to the rotor at the same time as particles near the rotor traveled in the same direction of the rotor.) This has imitated what happens inside a tornado. When a tornado hits the ground, the air-stream suddenly reverses inside the tornado. (This invention may also disassociate water, create ozone and hydrogen peroxide to assist in reducing the odor of the sewage, create N_2 , comminute rocks and materials containing oxygen, while at the same time producing Abrikosov vortices which aid fusion.)

The kinetic forces created in the apparatus invention are used in the method to bacteriostatically and bacteriocidally treat the microorganisms and pathogens that are present in the biosolids described above. This treatment enables the materials to be used beneficially by reducing the public health risks normally associated with direct exposure to these biosolids materials. For example, treatment of municipal sludges and septage is necessary for it to be used for beneficial reuse. The United States Environmental Protection Agency has written rules, i.e., 40 CFR Part 503, the so-called sludge rules indicating that these materials must obtain a Class A or Class B specification. The apparatus and method taught in this invention will partly or completely permit treated biosolids to reach these microbiological specifications.

The methods of this invention will utilize the kinetic energy processes of a cyclone air stream, vacuum forming centripetal vortices moving at supersonic speeds, powerful reverse vortices, harmonics and subharmonics, supersonic resonance, standing waves, thermal shock, pressure changes, sonic cavitation as created in the apparatus of the invention.

The method of this invention may further include the addition of disinfectants selected from the group including chlorine, chlorine dioxide, copper sulfate, ammonia, ammonium, sodium chlorite and ozone, any or all of which may be placed into the air stream of the apparatus described herein to augment and/or synergistically affect the disinfection process described herein. Figures 12-15 depict a preferred embodiment of a sewage treatment apparatus and rotor according to the present invention. Apparatus 300 consists of a high speed motor 340 attached to the rotor 310, a product discharge exit tube area 360, a specially configured nine or ten blade rotor 310 rotating horizontally or vertically, contained in a scrolled housing 330, attached to which is a conical section 320 which slopes downwards at an angle of about 9.7 degrees attached to a formula designed feed inlet tube 325. The inlet tube is preferably parallel and in line with the fan axis. The inlet tube 325 can be mounted horizontally, or vertically with the inlet tube sucking the material upwards due to the high air velocity created by the rotor. Gravity pulling on the sewage will reduce the velocity of the sewage, allowing the reverse vortex further time to treat the sewage.

The blades 311 are preferably 5 to 6 mm thick, and may be coated to assist with any wear rate problem. The blades lean back 5 degrees from the center of the hub 312 - whose diameter is preferably not be over 13% of the diameter of the rotor 310 - which also has a specially configured interrupter 350 attached to it - the height of which does not protrude into the conical section 320 beyond the leading edge of the blade. Preferably, the blade 311 does not protrude into the conical section 320 than 14.8% of its maximum width. The feed inlet tube 325 has a diameter equal to one-third the diameter of the rotor 310 and the conical section 320 where it is attached to the housing - is two-thirds the diameter of the rotor 310. The scrolled housing 330 should be as small as possible, for example a clearance of only 10 mm widening to 120 mm, whilst allowing for the free

movement of the rotor 310 which has a maximum width at its top, equal to 88% of the diameter of the inlet tube 325. (This rotor width is reduced to only 44% by the time it reaches the hub as its configuration is such that there is a 13 degree angle on one side of the blade and a 45 degree angle on the opposite leading edge side of the blade, which shortens the width of the blade. The 45 degree angle begins one-third of the length of the blade up from the hub.) As best shown in Figures 15 a and b, interrupter 350 has two semi-spherical mounds 301 and 302 side by side, one having a diameter equal to 42% the diameter of the hub 312, and the other 21%. Mid-way up, both have a hole drilled in them, from one side to the other, that has a diameter no greater than 10% of the diameter of the hub 312. The discharge exit tube area will have the same area as the inlet tube diameter. The diameter of the rotor 310 is equal to 41% of the total length of the combined conical section and inlet tube. Therefore a typical rotor diameter of 610 mm will have a total feed in length of 1481 mm. This 610 mm diameter rotor configuration would require a high speed motor, typically 200 Kw, that is capable of turning the rotor at a speed of 96 cycles per second (cps) and maintaining that precise speed (to + or - 1 cps) under load. It is essential for the formation of the reverse vortex - and the centripetal boundary envelope within the conical section that the inlet tube connection to the conical section 320, and the conical section connection to the housing in front of the rotor, is perfectly smooth to allow a smooth laminar flow.

The invention may also utilize a feed assembly conveyor system.

As shown in Figures 12-15, apparatus 300 comprises a conical section 320 with an inlet tube 325, a rotor 310 for creating reverse vortices upstream in a cyclonic air-stream. The rotor 310 has an inlet for the movement of the air-stream and sewage. The rotor further has an outlet corridor 360 with an exit tube having a discharge opening. The apparatus further has a feed inlet

tube 325 for feeding the sewage into the centripetal boundary envelope, in the conical section 320, within the reverse vortex for treating and processing the sewage in the conical section 320 and rotor 310. Preferably, the wider area of the conical section is preferably 67% the diameter of the rotor 310. Rotor housing 330, which is preferably scrolled, surrounds rotor 310. Rotor 310 has blades 311 and central hub 312. High speed motor 340 is attached to the rotor 310.

To determine the ideal configuration of the invention a formula is used to determine the ideal combined length of the inlet tube and conical section. This is because all parts of the invention are fixed in dimension in relation to the other parts. The simple formula is to divide either the speed (of the rotor, the air, or the passage of material in the air) by the frequency of either the material to be processed or the rotor. This will create a fundamental standing wave down the inlet tube that is specific to the material. When the standing wave is achieved the dimensions of all the parts can then be determined. This standing wave will also assist the treatment and processing, within the boundary envelope, inside the reverse vortex which in turn is situated inside the conical section.

However, should the apparatus be built using, for example, a 610 mm diameter rotor, the frequency may be such that a different length of feed tube would be required to suit the chosen material. The inlet tube length would then be fixed according to the standing wave created.

Accordingly, one embodiment of the invention is directed to an apparatus for processing and treating sewage comprising a conical section with an inlet tube, a rotor for creating reverse vortices upstream in a cyclonic air-stream, the rotor having an inlet for the movement of the air-stream and sewage, and an outlet corridor with exit tube, a feed inlet tube for feeding the sewage into a centripetal boundary envelope in the conical section, within the reverse vortex for treating and

processing the sewage in the conical section and rotor. Preferably, the conical section has a wider area which is 67% the diameter of the rotor. The wider area of the conical section may be attached to a housing.

Preferably, the inlet tube has a diameter equal to 34% of the rotor's diameter. The invention may further comprise a rotor housing for the rotor. Preferably, the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus. The rotor preferably has nine or ten radially extending blades, the leading edge of each blade extending not more than 14.8%, of the blades' maximum width, into the conical section.

Another embodiment is directed to an apparatus for processing and treating sewage comprising: a conical section having an inlet tube; a rotor for creating reverse vortices upstream in a cyclonic air-stream within the conical section, the rotor having an inlet and outlet corridor for the passage of the air-stream and sewage; a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope in the conical section within the reverse vortex for treating and processing the sewage within the conical section and rotor. The area on the inlet of the rotor is preferably 67% of the rotor's diameter. Preferably, the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus. The apparatus may further comprise a rotor housing for containing the rotor, the rotor having nine or ten radially extending 5-6 mm blades, the leading edge of each blade extending not more than 14.8%, of the blades' maximum width into the conical section. Preferably, the diameter of the inlet of the rotor is 67% of the rotor's diameter. In a preferred embodiment, the outlet corridor has an exit tube, and the discharge of the exit tube of the rotor has an area which is equal in area to 34% of the rotor's circumferential inlet area. The exit of the outlet tube of the rotor is preferably equal to 34% of the rotor's circumferential

inlet area. Another embodiment is directed to an apparatus for processing and treating sewage comprising a conical section with an inlet tube, a rotor housing for containing a rotor, the rotor housing having an inlet and an outlet, a rotor having nine or ten radially extending blades for creating reverse vortices upstream in a cyclonic air-stream within the conical section via the inlet of the rotor, and a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope within the reverse vortex for treating and processing the sewage within the conical section and rotor. Preferably, the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus. Preferably, the leading edge of each blade of the rotor extends not more than 14.8% of the blades maximum width into the conical section.

Another embodiment is directed to an apparatus for treating and processing sewage comprising a conical section with an inlet tube; a rotor for creating reverse vortices upstream in a cyclonic air-stream; and a feed inlet tube for feeding the sewage into the centripetal boundary envelope within the reverse vortex for treating and processing the sewage in the inlet tube, conical section and rotor, wherein the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus. The invention may further comprise a rotor housing for containing the rotor, the rotor having nine or ten radially extending blades, the leading edge of each blade extending not more than 14.8% of the blades maximum width into the conical section.

Another embodiment is directed to an apparatus for processing and treating sewage comprising; a conical section with an inlet tube; a rotor housing for containing a rotor, the rotor housing having an inlet and an outlet; a rotor having nine or ten radially extending blades for creating reverse vortices upstream in a cyclonic air-stream within the 9.7 degree sloping conical

section via the inlet of the rotor housing; a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope within the reverse vortex for treating and processing the sewage within the conical section and rotor, wherein the leading edge of each of the blades of the rotor extends not more than 14.8% of the blades maximum width into the conical section.

As will be clear to those of skill in the art, any of the embodiments disclosed herein may have any or all of its parts coated with an abrasion resistant material.

The apparatuses of the present invention may further comprise a feed assembly which comprises a conveyor that leads to the inlet tube so that sewage may be fed into the air-stream. The distance between the conveyor and the inlet tube is preferably up to 610 mm.

Another embodiment is directed to a rotor for a sewage processing treatment invention comprising: a central hub having a diameter which is no more than 13% of the rotor's diameter, nine or ten blades extending radially from the hub for creating reverse vortices upstream in a cyclonic air-stream, the blades extending forwards from the hub of the rotor at an angle of 45 degrees. The rotor may further comprise an interrupter located on the hub.

Another embodiment is directed to a rotor for treating and processing sewage comprising: a central hub; nine or ten blades extending radially from the hub for creating a reverse vortex upstream in front of the rotor; and an interrupter located on the hub. The blades preferably extend radially at an angle of 5 degrees back from the center of the hub. Preferably, each blade is concave in profile and the concavity faces in the direction of rotation of the rotor, and the diameter of the interrupter is 90% of the diameter of the hub. Preferably, every part of the apparatus is coated with an abrasion resistant material. Another embodiment of the invention is directed to processes for processing and

treating sewage using any of the above described apparatuses, wherein water contained in sewage has its chemical structure altered, for example into hydrogen peroxide.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein pathogens are removed.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein water contaminated by sewage is purified.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein water is disassociated into hydrogen and oxygen.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein Ozone is created to remove the smell of the sewage.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein N_2 is created.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein Abrikosov vortices are formed to aid fusion.

Another embodiment of the invention is directed to processes for processing and treating sewage using any of the above described apparatuses, wherein an inlet tube which is vertical utilizes gravity to slow the flow of sewage into the air-stream, thereby enhancing the processing and treatment of material.

Another embodiment of the invention is directed to any of the above described apparatuses, wherein rocks, or material containing oxygen, are comminuted.

Another embodiment of the invention is directed to any of the above described apparatuses, wherein rotor diameter of 610 mm equates to a rotor speed of 95 to 97 cycles per second.

Another embodiment of the invention is directed to any of the above described apparatuses, wherein the conical section and inlet tube is 1481 mm; a rotor traveling at 95 to 97 cycles per second for the configuration of reverse vortices will comminute material upstream, in front of the rotor, inside the conical section.

Another embodiment relates to apparatus and methods incorporating the formulas described herein, wherein the configuration of all dimensions of the apparatus are related to each other, based on the process wherein speed is divided by the frequency to create a fundamental standing wave.

The present invention is also directed to methods using the apparatus of the invention to treat sewage and biosolids. One embodiment of the present invention is directed to a method for treating biosolids using of apparatus of the present invention. Biosolids may be selected from the group consisting of sewage, sewage sludge, municipal sewage sludge, septage, manures, animal waste, slaughter house offel, pharmaceutical fermentation waste, industrial biosolids, agricultural wastes, food wastes, spent hens, paper mill waste, borgass. The method can be carried out according to any of the embodiments of the invention. The method is preferably carried out in combination with an apparatus having a rotor according to the present invention. In a preferred embodiment, the method creates destructive kinetic energy.

Another embodiment of the invention is directed to a method which utilizes the kinetic energy processes of a cyclone air stream, vacuum forming centripetal vortices moving at supersonic speeds, harmonics and subharmonics, supersonic resonance, standing waves, thermal shock, pressure changes, sonic cavitation as created by the present invention.

Another embodiment of the invention is directed to an apparatus, wherein said apparatus is used to treat biosolids selected from the group consisting of sewage, sewage sludge, municipal sewage sludge, septage, manures, animal waste, slaughter house offel, pharmaceutical fermentation waste, industrial biosolids, agricultural wastes, food wastes, spent hens, paper mill waste, and borgass which utilize the process of ultrasound.

Treatment as defined in the present invention may include, for example, reducing water contained in biosolids, reducing average particle diameter of the biosolids, granulating the biosolids or converting water contained in the biosolids by dissociation into gases. In a preferred embodiment, the water is converted wholly, or in part, into gases. The gases of the present invention may be selected from hydrogen, oxygen, ozone, hydrogen peroxide and water vapor. In a preferred embodiment, nitrogen gas is created.

The biosolids of the present invention may comprise microbial organisms. Thus, another embodiment of the invention is directed to a method comprising treatment of said microbial organisms. Treatment comprises affecting the viability of the microbial organisms, such as, for example, by destroying the microbial organisms. In a preferred embodiment, the destruction is carried out bacteriocidally or bacteriostatically. Preferably the treatment conforms to microbiological treatment regulations specified in the 40 CFR Part 503 by the United States Environmental Protection Agency referred to as Class A. Alternatively, the treatment method of the

present invention conforms to microbiological treatment regulations specified in the 40 CFR Part 503 by the United States Environmental Protection Agency referred to as Class B.

The microbial organisms of the present invention may include bacteria, viruses, fungi, parasites or algae. In a preferred embodiment, the organisms are pathogens. The biosolids of the present invention may emit an odor. In a preferred embodiment, the gases produced by the invention reduce the odor.

Another embodiment of the invention is directed to an apparatus useful in pasteurizing biosolids. Alternately, the apparatus may be useful in sterilizing the biosolids. The apparatus may further comprise an inlet tube, wherein said inlet tube is vertical and utilizes gravity to slow the flow of biosolids into the air-stream, thereby enhancing processing and treatment of said biosolids.

Another embodiment of the invention is directed to a method wherein additional disinfectants selected from the group consisting of chlorine, chlorine dioxide, copper sulfate, ammonia, ammonium, sodium chlorite are placed into the air stream of the apparatus of the present invention to augment and/or synergistically affect the disinfection process. In a preferred embodiment, the method comprises formation of Abrikosov vortices to aid fusion.

The drying of biosolids that are difficult to dewater may be enhanced by adding drying agents or materials to the input to the apparatus. The drying agents may include, for example, previously processed biosolids of the invention, soils or other mineral products. These materials may be selected specifically for their nutrient content, for example, ammonium, nitrate, potassium, phosphate or sulfur containing compounds in order to enhance the nutrient value of the finished product, thereby creating a product with greater beneficial value.

In one example using the foregoing invention, centrifuged raw sludge cake was spread onto a horizontal conveyer belt in an even layer with the end of the conveyer placed near to the open end of the feed tube. The grinder was running at 5,760 rpm and the conveyer belt was started to feed the biosolids into the grinder. All biosolids were sucked into the feed tube and powder came out from the bottom of the cyclone.

Apparatus of the invention has been used to dry sewage sludge cake which was introduced into the path of the cyclonic air stream created by the impeller within the cyclone chamber running at a speed of 5,760 rpm. The biosolids were fed into the inlet tube from a horizontal conveyer at a measured feed rate of 4,000 kg/hr. The biosolids entering the inlet tube of the apparatus comprised 78% water and 22% solids. The dried biosolids leaving the cyclone chamber of the apparatus and collected from the bottom of an attached cyclone comprised 20% water and 80% solids.

While the foregoing disclosure and description of the invention is illustrative and explanatory thereof, various changes in the method steps as well as the details of the illustrated preferred embodiment may be made without departing from the scope and spirit of the invention. Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. All references cited herein, including all U.S. and foreign patents and patent applications, including U.S. Patent Nos. 3,147,911; 3,255,793; 4,390,131; 4,391,411 and 4,892,261, are specifically and entirely incorporated herein by reference. The specification should be considered exemplary only with the true scope and spirit of the invention indicated by the following claims.

We Claim:

1. Apparatus for processing and treating sewage comprising:
a conical section with an inlet tube;
a rotor for creating reverse vortices upstream in a cyclonic air-stream, the rotor having an inlet for the movement of the air-stream and sewage, and an outlet corridor with an exit tube; and a feed inlet tube for feeding the sewage into a centripetal boundary envelope in the conical section, within the reverse vortex for treating and processing the sewage in the conical section and rotor.
2. Apparatus according to claim 1, wherein said conical section has a wider area, wherein the wider area of the conical section is attached to a housing, and wherein said wider area which is attached to the housing is 67% the diameter of the rotor.
3. Apparatus according to claim 1, wherein the area of the inlet of the rotor is 67% the diameter of the rotor.
4. Apparatus according to claim 1, wherein the inlet tube has a diameter equal to 34% of the rotor's diameter.
5. Apparatus according to claim 1, wherein, the invention further comprises a rotor housing for the rotor, and wherein the rotor has 9 or 10 radially extending blades.
6. Apparatus according to claim 1, wherein a length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus.
7. Apparatus according to claim 1, wherein, the invention further comprises a rotor housing for containing the rotor, the rotor having nine or ten radially extending blades, the leading edge of each blade extending not more than 14.8% of the blades' maximum width, into the conical section.

8. Apparatus for processing and treating sewage comprising:
 - a conical section having an inlet tube;
 - a rotor for creating reverse vortices upstream in a cyclonic air-stream within the conical section, the rotor having an inlet and outlet corridor for the passage of the air-stream and sewage; and a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope in the conical section within the reverse vortex for treating and processing the sewage within the conical section and rotor.
9. Apparatus according to claim 8, wherein the area on the inlet of the rotor is 67% of the rotor's diameter.
10. Apparatus according to claim 8, further comprising a rotor housing for containing the rotor, wherein the rotor has nine or ten radially extending blades.
11. Apparatus according to claim 8, wherein a length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus.
12. Apparatus according to claim 8, wherein the apparatus further comprises a rotor housing for containing the rotor, the rotor having nine or ten radially extending blades, the leading edge of each blade extending not more than 14.8% of the blades' maximum width into the conical section.
13. Apparatus according to claim 8, wherein the diameter of the inlet of the rotor is 67% of the rotor's diameter.
14. Apparatus according to claim 8, wherein the outlet corridor has an exit tube, and the discharge of the exit tube of the rotor has an area which is equal in area to 34% of the rotor's circumferential inlet area.

15. Apparatus according to claim 8, further comprising a rotor housing for containing the rotor, the rotor having 9 or 10 radially extending 5 - 6 mm thick blades.
16. The apparatus of claim 8 wherein the inlet tube is vertical.
17. The apparatus of claim 8 wherein one or more components of the apparatus are coated with an abrasion resistant material.
18. Apparatus according to claim 8, wherein the exit of the outlet corridor of the rotor is equal to 34% of the rotor's circumferential inlet area.
19. Apparatus for processing and treating sewage comprising:
 - a conical section with an inlet tube;
 - a rotor housing for containing a rotor, the rotor housing having an inlet and an outlet;
 - a rotor having nine or ten radially extending blades for creating reverse vortices upstream in a cyclonic air-stream within the conical section via the inlet of the rotor;
 - and a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope within the reverse vortex for treating and processing the sewage within the conical section and rotor.
20. Apparatus according to claim 19, wherein the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus.
21. Apparatus according to claim 19, wherein the leading edge of each blade of the rotor extends not more than 14.8% of the blades maximum width into the conical section.
22. An apparatus for treating and processing sewage comprising:
 - a conical section with inlet tube;
 - a rotor for creating reverse vortices upstream in a cyclonic air-stream; and

a feed inlet tube for feeding the sewage into the centripetal boundary envelope within the reverse vortex for treating and processing the sewage in the inlet tube, conical section and rotor, wherein the length of the conical section and inlet tube is fixed in relation to the entire configuration of the apparatus.

23. Apparatus according to claim 22, wherein the invention further comprises a rotor housing for containing the rotor, the rotor having nine or ten radially extending blades, the leading edge of each blade extending not more than 14.8% of the blades maximum width into the conical section.
25. Apparatus for processing and treating sewage comprising;
 - a conical section with an inlet tube;
 - a rotor housing for containing a rotor, the rotor housing having an inlet and an outlet;
 - a rotor having nine or ten radially extending blades for creating reverse vortices upstream in a cyclonic air-stream within the 9.7 degree sloping conical section via the inlet of the rotor housing; and
 - a feed inlet tube for feeding the sewage into the path of the centripetal boundary envelope within the reverse vortex for treating and processing the sewage within the conical section and rotor, wherein the leading edge of each of the blades of the rotor extends not more than 14.8% of the blades maximum width into the conical section.
26. Apparatus according to claim 1 wherein any part of the invention may be coated with an abrasion resistant material.
27. Apparatus according to claim 1, further comprising a feed assembly which comprises a conveyor that leads to the inlet tube so that sewage may be fed into the air-stream.

28. Apparatus according to claim 27, wherein the distance between the conveyor and the inlet tube is up to 610 mm.
29. A rotor for a sewage processing treatment invention comprising:
a central hub, said hub having a diameter which is no more than 13% of the rotor's diameter; and nine or ten blades extending radially from the hub for creating reverse vortices upstream in a cyclonic air-stream, the blades extending forwards from the hub of the rotor at an angle of 45 degrees.
30. A rotor according to claim 29 further comprising an interrupter located on the hub.
31. A rotor for treating and processing sewage comprising:
a central hub;
nine or ten blades extending radially from the hub for creating a reverse vortex upstream in front of the rotor; and
an interrupter located on the hub.
32. A rotor according to claim 31, wherein each blade extends radially at an angle of 5 degrees back from the center of the hub.
33. A rotor according to claim 31, wherein each blade is concave in profile and the concavity faces in the direction of rotation of the rotor.
34. A rotor according to claim 31, wherein the diameter of the interrupter is 90% of the diameter of the hub.
35. A rotor according to claim 31, wherein every part of the apparatus is coated with an abrasion resistant material.

36. Apparatus according to claim 1, wherein rocks, or material containing oxygen, are comminuted.
37. Apparatus according to claim 1, wherein a rotor diameter of 610 mm equates to a rotor speed of 95 to 97 cycles per second.
38. Apparatus of claim 1 wherein the conical section and inlet tube is 1481 mm; the rotor travels at 95 to 97 cycles per second such that the configuration of reverse vortices will comminute material upstream, in front of the rotor, inside the conical section.
39. A method for treating biosolids comprising the apparatus of claim 1, wherein said biosolids are selected from the group consisting of sewage, sewage sludge, municipal sewage sludge, septage, manures, animal waste, slaughter house offal, pharmaceutical fermentation waste, industrial biosolids, agricultural wastes, food wastes, spent hens, paper mill waste, and bagasse.
40. The method of claim 39, wherein destructive kinetic energy is created.
41. The method of claim 39, wherein kinetic energy processes of a cyclone air stream, vacuum forming centripetal vortices moving at supersonic speeds, harmonics, subharmonics, supersonic resonance, standing waves, thermal shock, pressure changes and sonic cavitation as created in said apparatus are utilized.
42. A method wherein the apparatus of claim 39 utilizes the process of ultrasound.
43. A method for reducing water contained in the biosolids of claim 39.
44. A method for reducing the biosolids of claim 39, wherein the average particle diameter of said biosolids is reduced.
45. A method for drying the biosolids of claim 39.
46. The method of claim 40, wherein said biosolids are granulated or powdered.

47. The method of claim 45, wherein, the drying may be enhanced by the addition of drying agents.
48. A method wherein water contained in the biosolids of claim 39 is converted by dissociation into gases.
49. The method of claim 48 wherein said water is converted wholly, or in part, into said gases are selected from hydrogen, oxygen, ozone, hydrogen peroxide and water vapor.
50. The method of claim 39, wherein said biosolids contain microbial organisms.
51. The method of claim 50, further comprising treatment of said microbial organisms.
52. The method of claim 52, wherein said treatment destroys the microbial organisms.
53. The method of claim 52, wherein destroying is carried out bacteriostatically.
54. The method of claim 52, wherein destroying is carried out bacteriocidally.
55. The method of claim 50, wherein said microbial organisms are pathogens.
56. The method of claim 39, wherein said apparatus pasteurizes said biosolids.
57. The method of claim 39, wherein said apparatus sterilizes said biosolids.
58. The method of claim 50, where the microbial organisms are bacteria, viruses, fungi, parasites or algae.
59. The method of claim 51 wherein said treatment conforms to microbiological treatment regulations specified in the 40 CFR Part 503 by the United States Environmental Protection Agency referred to as Class A.
60. The method of claim 51, wherein said treatment conforms to microbiological treatment regulations specified in the 40 CFR Part 503 by the United States Environmental Protection Agency referred to as Class B.

61. The method of claim 48, wherein the biosolids emit an odor.
62. The method of claim 48, wherein the gases reduce said odor.
63. The method of claim 48, wherein nitrogen gas is created.
64. The method of claim 39, wherein Abrikosov vortices are formed to aid nuclear fusion and enhance the destructive treatment of the biosolids.
65. The method of claim 39, wherein said apparatus further comprises an inlet tube, wherein said inlet tube is vertical and utilizes gravity to slow the flow of biosolids into the air-stream, thereby enhancing processing and treatment of said biosolids.
66. A method wherein additional disinfectants selected from the group consisting of chlorine, chlorine dioxide, copper sulfate, ammonia, ammonium, sodium chlorite are placed into the air stream of the apparatus described in claim 39 to augment and/or synergistically affect the disinfection process.
67. A method wherein the biosolids of claim 39 are supplemented to produce a fertilizer and soil conditioner.
68. The method of claim 39, wherein gamma emitters are formed.
69. A method wherein the biosolids of claim 39 may be augmented by nutrient containing compounds or material in order to enhance the beneficial value of the finished product.

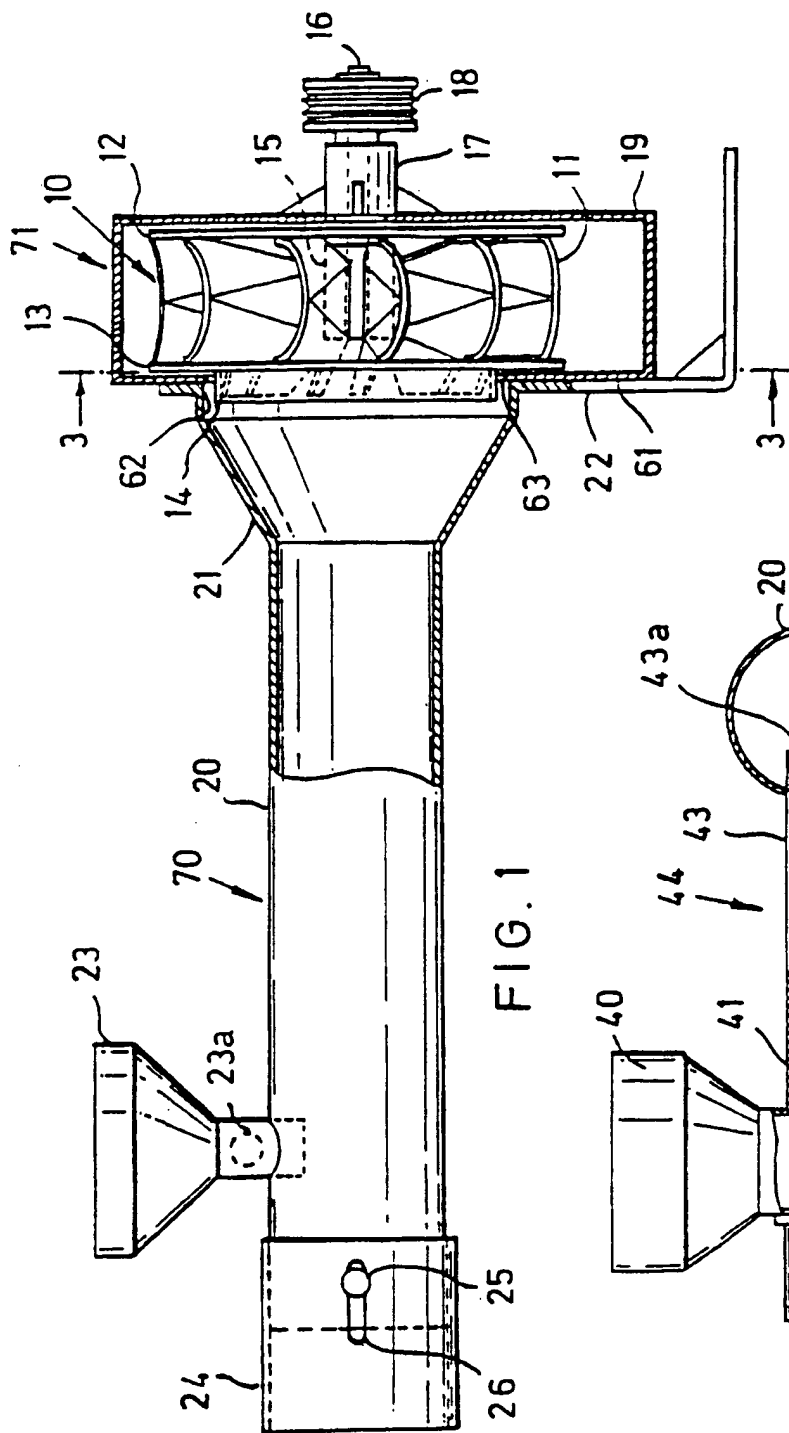


FIG. 1

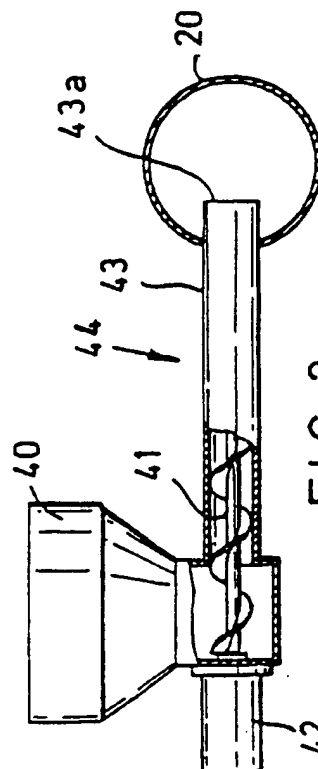


FIG. 2

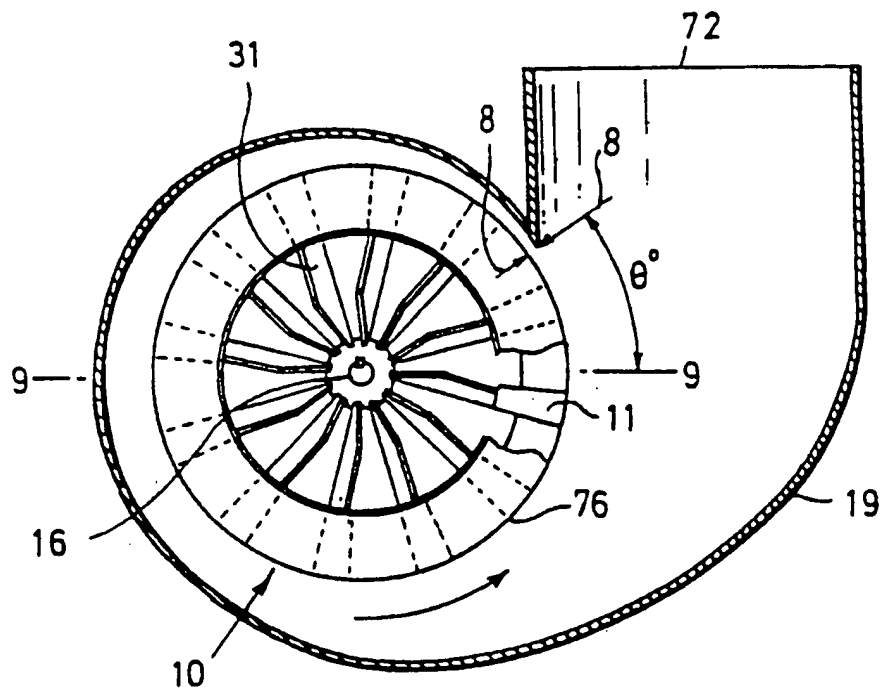


FIG. 3

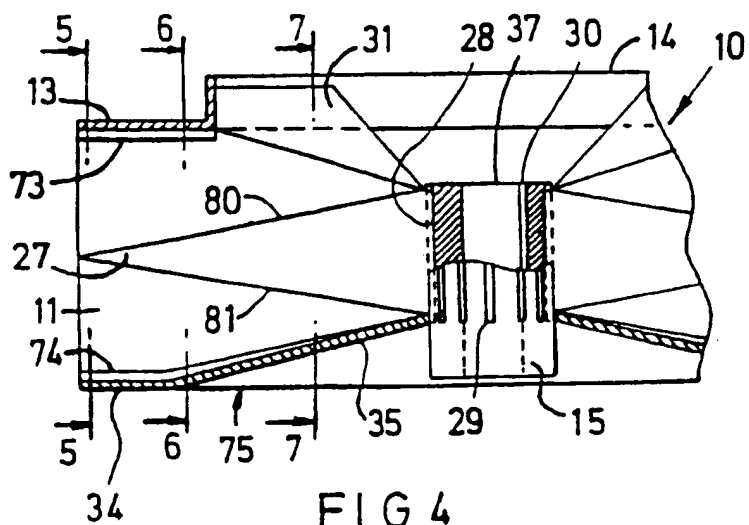


FIG. 4

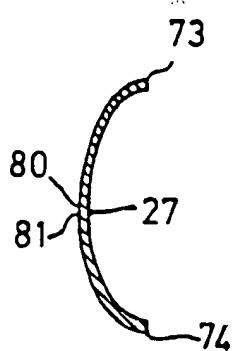


FIG. 5

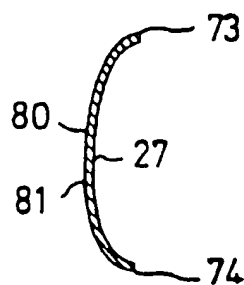


FIG. 6

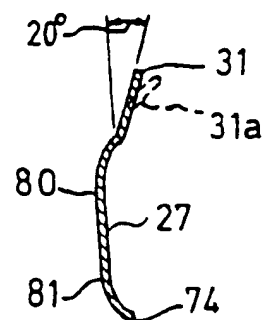


FIG. 7

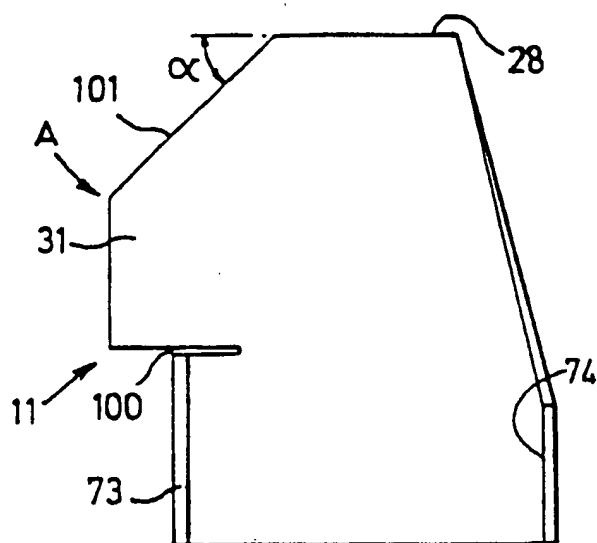


FIG. 8



FIG. 9

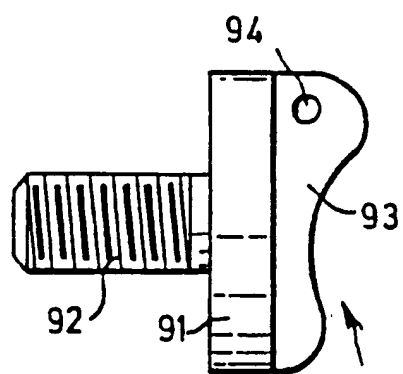


FIG. 10a

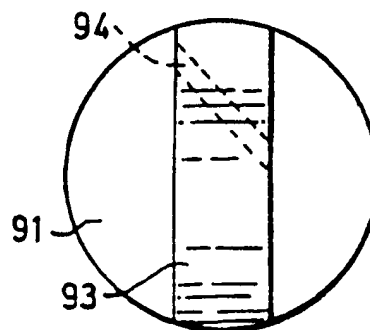


FIG. 10b

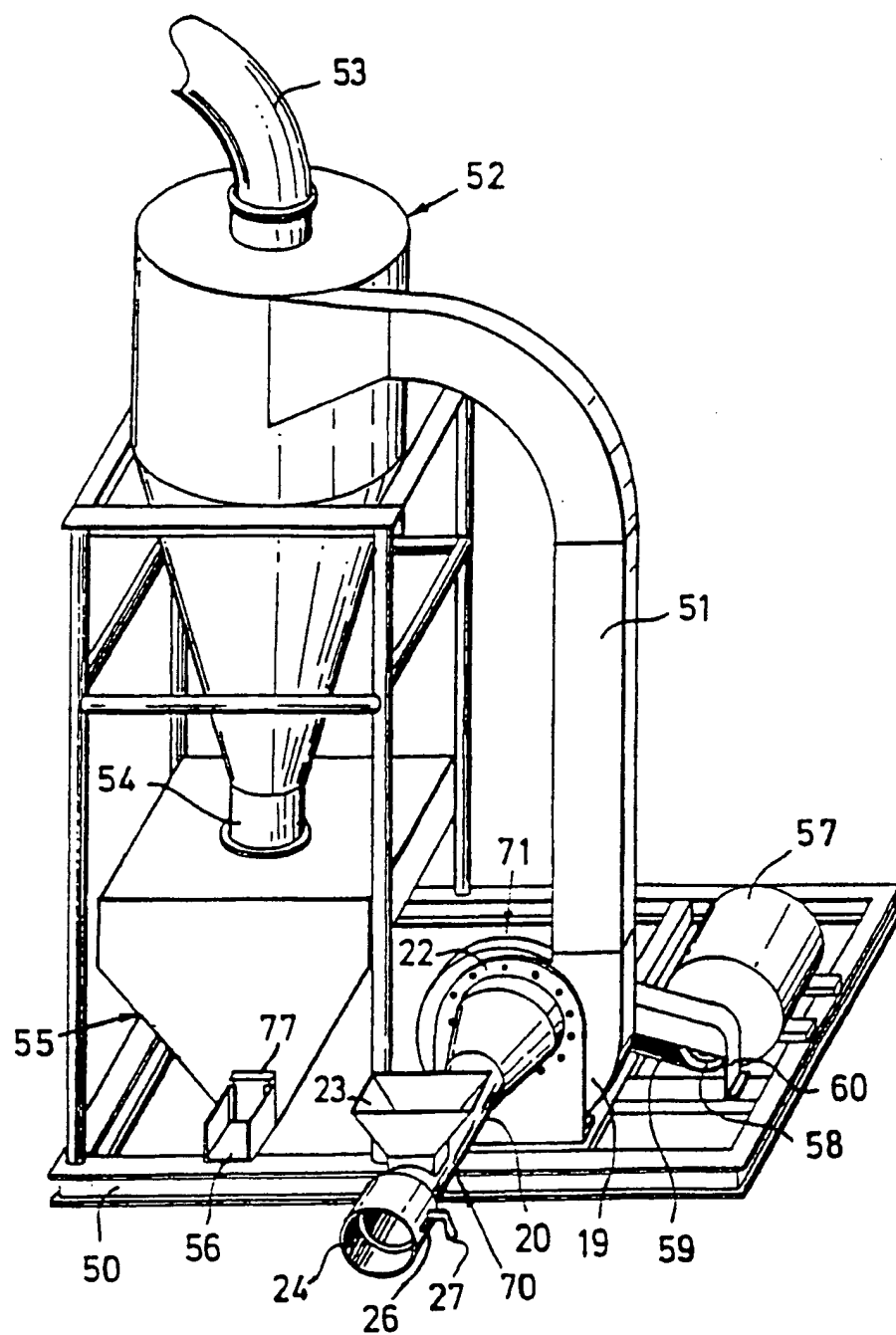


FIG. 11

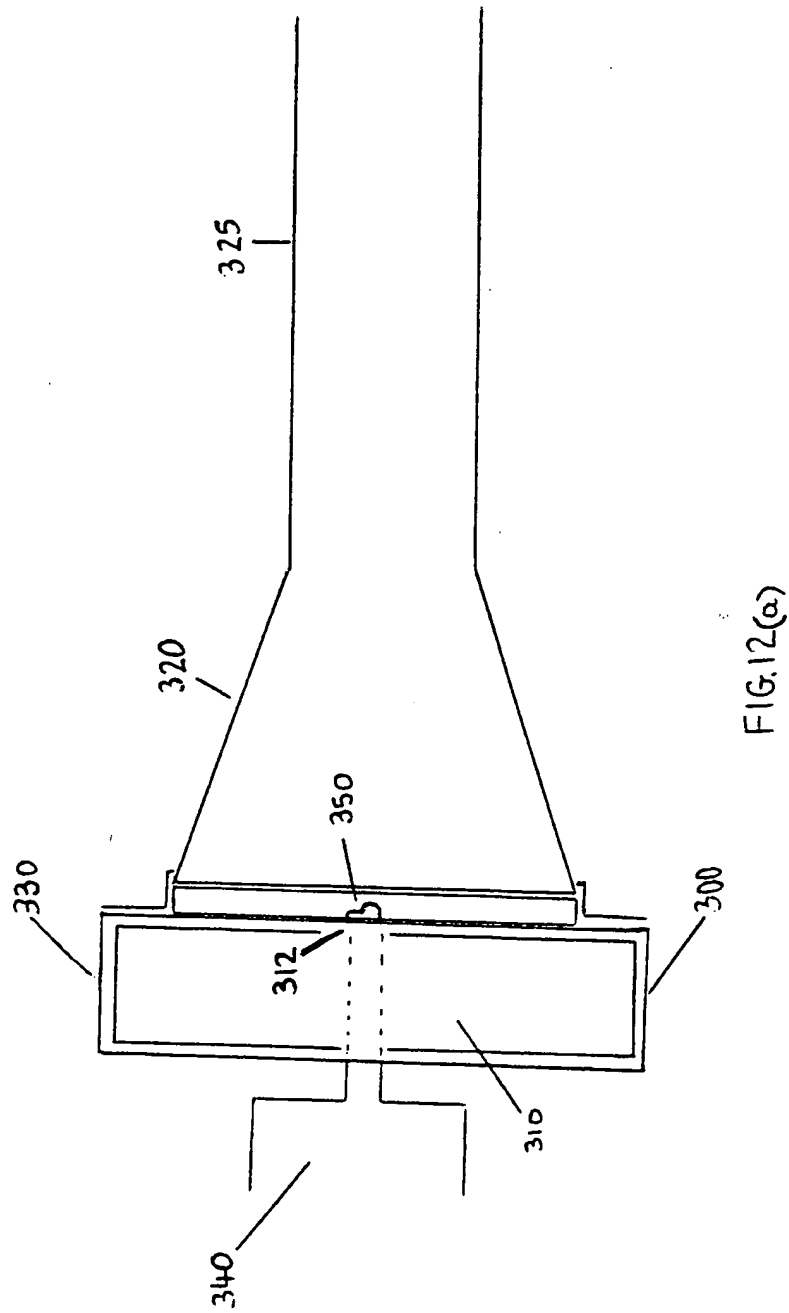
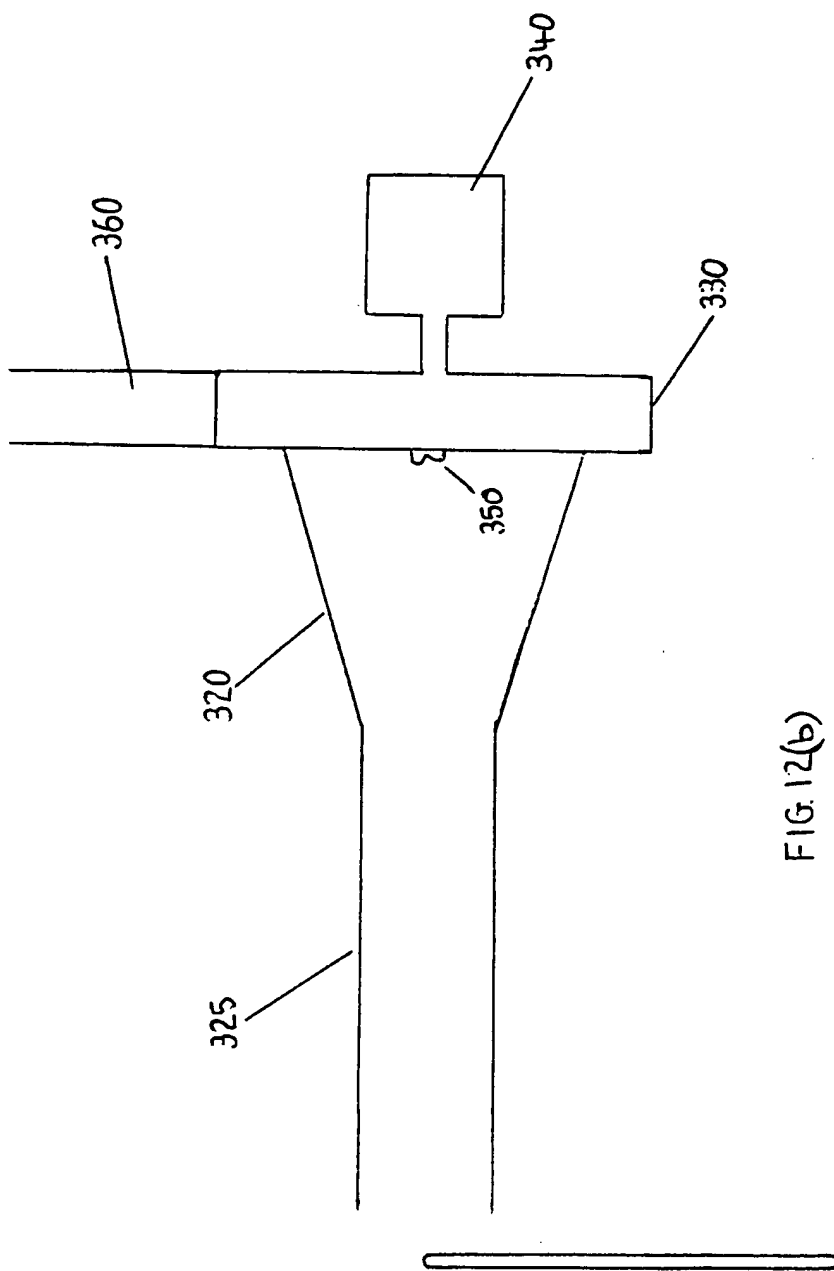
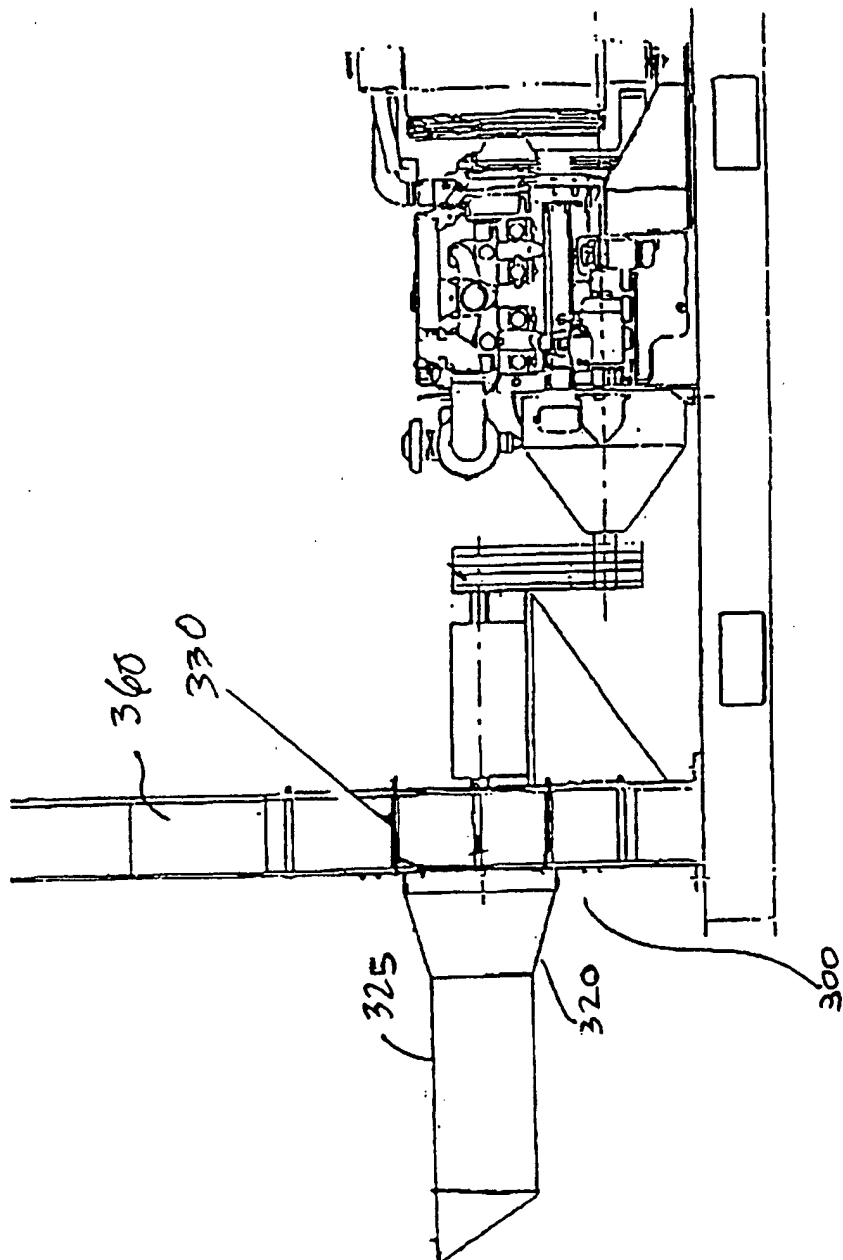


FIG. 12(a)





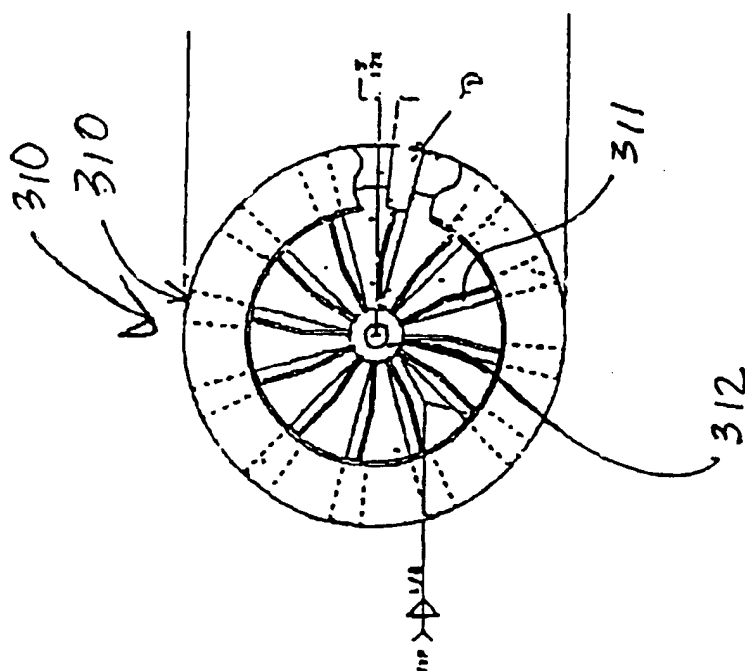


FIG. 14

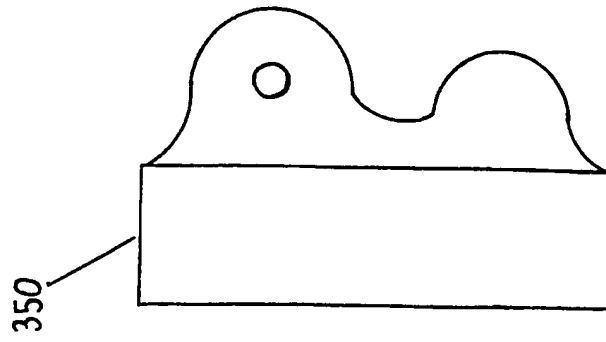


FIG. 15(b)

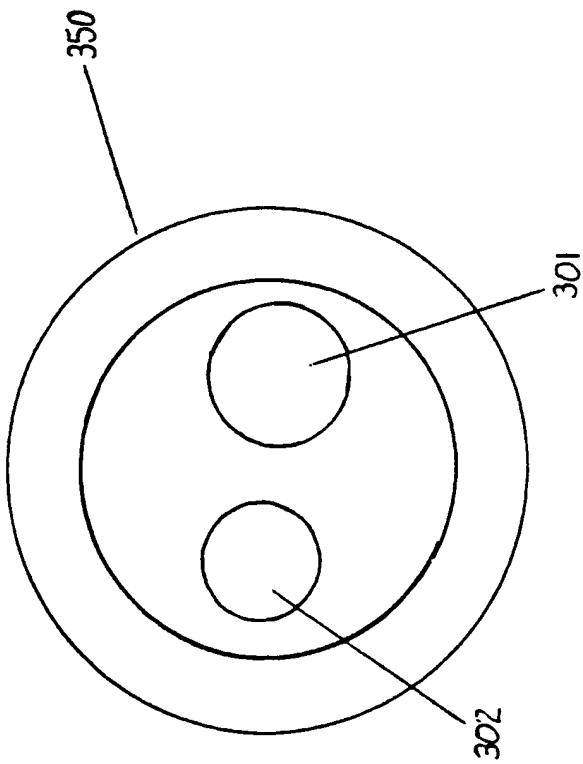


FIG. 15(a)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
22 February 2001 (22.02.2001)

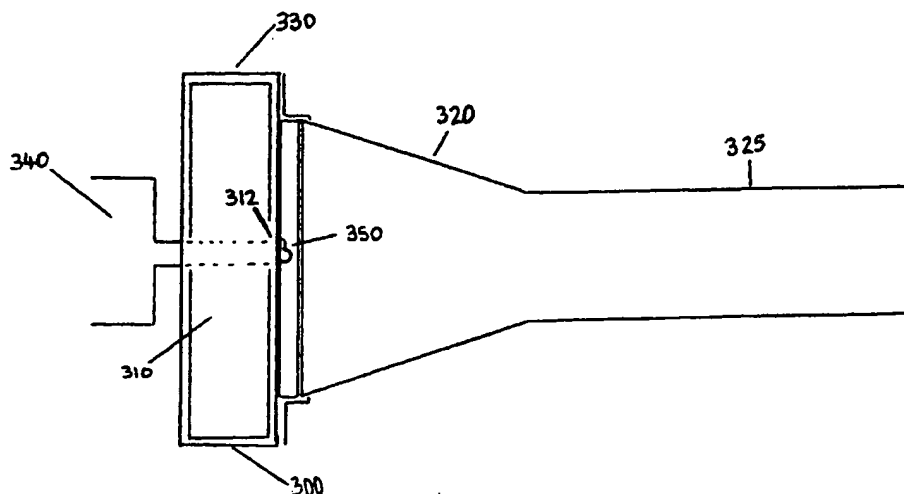
PCT

(10) International Publication Number
WO 01/12332 A3

- (51) International Patent Classification⁷: B02C 19/00, 19/06, F04D 29/28, C05F 7/00
- (21) International Application Number: PCT/GB00/03071
- (22) International Filing Date: 9 August 2000 (09.08.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
09/372,096 11 August 1999 (11.08.1999) US
- (71) Applicant: **HELIX COMMUNITIONS LIMITED**
[GB/GB]; Apple Tree House - Main Street, East Haddon,
Northants NN6 8BU (GB).
- (72) Inventors: **JARRETT, Colin**; Apple Tree House-Main
Street, East Haddon, Northants NN6 8BU (GB). **BURN-**
HAM, Jeffrey; 2741 Ardisia Lane, Naples, FL 34109
(US). **HAMPTON, Arthur**; 24 Dark Lane, Wargrave,
Reading, Berks RG10 8JU (GB).
- (81) Designated States (*national*): AU, BR, CA, CN, DE, ES,
GB, IL, IN, JP, KP, KR, MX, NO, NZ, PL, PT, RO, RU,
TR, UA, YU, ZA.
- (84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,
IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG,
CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report
- (88) Date of publication of the international search report:
17 January 2002
- (71) Applicant and
(72) Inventor: **YOUNDS, Mark** [GB/GB]; 158 Monkleigh
Road, Morden, Surrey SM4 4ES (GB).

[Continued on next page]

(54) Title: METHODS AND APPARATUS FOR SEWAGE PROCESSING AND TREATMENT



(57) Abstract: An apparatus for processing and treating biosolids such as sewage, whereby drying and elimination of pathogens takes place, comprises a feed assembly with conical section (320) and inlet tube (325) having a discharge area and inlet area for the passage of air and sewage and a rotor (310) for creating reverse vortices in a cyclonic air-stream within the conical section (320) and inlet tube (325). A formula is utilized which is configured to also create a fundamental standing wave, to assist treatment and processing of sewage, and a centripetal boundary envelope inside the conical section.

WO 01/12332 A3



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/03071

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B02C19/00 B02C19/06 F04D29/28 C05F7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B02C F04D C05F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 35756 A (NEXT CENTURY TECHNOLOGIES LTD ;SEEBACH CHRISTOPHER F N (GB); JARRE) 20 August 1998 (1998-08-20) cited in the application the whole document ---	1,4-8, 10-12, 14,15, 17,19, 20,22, 23,25, 27,39
X	US 4 391 411 A (COLBURN WILLIAM A) 5 July 1983 (1983-07-05) cited in the application the whole document ---	1,8,16, 22

	-/--	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

26 March 2001

Date of mailing of the international search report

16.07.2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

GONZALEZ ARIAS, M

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/03071

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>US 3 255 793 A (CLUTE FRANCIS H) 14 June 1966 (1966-06-14) cited in the application column 4, line 19 -column 5, line 19; figures</p> <p style="text-align: center;">-----</p>	<p>1,8,19, 22,25</p>

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 00/03071

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-28, 36-69

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-28, 36-69

Apparatus and method for treating biosolids or sewage

2. Claims: 29-35

A rotor for processing sewage

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 00/03071

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9835756 A	20-08-1998	AU 6000998 A EP 1039970 A ZA 9801137 A	08-09-1998 04-10-2000 11-08-1998
US 4391411 A	05-07-1983	NONE	
US 3255793 A	14-06-1966	NONE	